some of the genera or species. For instance, in the *Compositae* endodermal ducts occur in many of the *Tubuliflorae*, in several of the *Labiatiflorae*, but only in a few *Cichoriaceae;* in the *Cornaceae* ducts are only known from *Mastixia,* in the *Caesalpinieae* from *Eperna* and *Copaifera,* etc.

Clinton, Maryland

Explanation of Plates 206 and 207.

(All the figures are of *Hamamelis Virginiana* L.)

Plate 206. Fig. 1, leaf of the tree; two-thirds of the natural size. Fig. 2, the seedling; natural size. Fig. 3, second proper leaf of a seedling; natural size. Fig. 4, cross-section of the hypocotyl of a seedling; Ep = epidermis, Co = cork, Coll. = collenchyma; × 480. Fig. 5, cross-section of the primary leaf of a seedling; Ep. = ventral, Ep* = dorsal epidermis, P = ventral chlorenchyma, P* = pneumatic tissue; × 480.

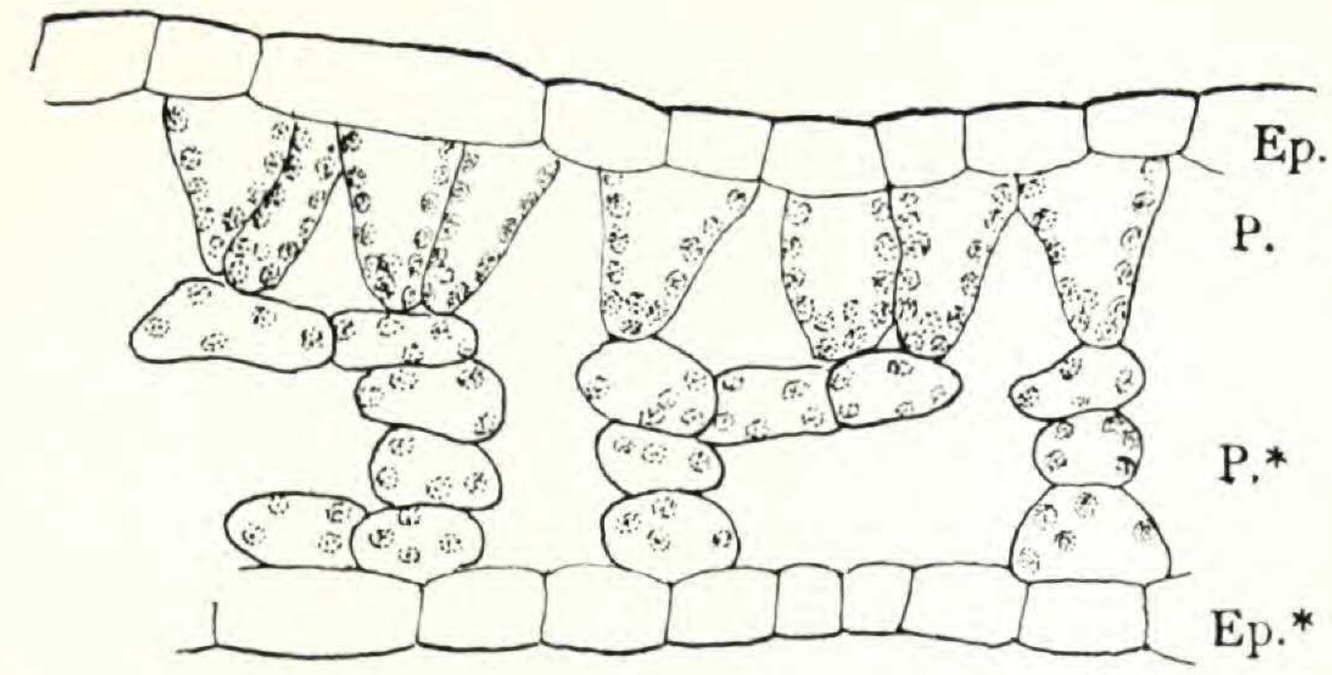
Plate 207. Fig. 6, cross-section of a branch in its first year, letters as in fig. 4; × 480. Fig. 7, cross-section of a leaf of the tree, showing a macrosclereid; letters as in fig. 5; × 480. Fig. 8, cross-section of the midrib of a leaf of the tree, Ep = ventral, Ep* = dorsal epidermis. The large, obtuse keel contains a stele of mestome surrounded by a sheath of stereome, bordering on the leptome, and outside this is a large-celled water-storage-tissue, surrounded by strata of peripheral collenchyma. Above the stele, close to the ventral epidermis, is a small, collateral mestome-strand; × 60.

PECULIAR ASPECTS OF THE NEW ENGLAND DISTRIBUTION OF ARCEUTHOBIUM PUSILLUM

R. J. Eaton

There is a diminutive roadside bog in Concord, Massachusetts, where Thoreau first discovered *Ledum groenlandicum* Oeder seventy-five years ago. Typical associates are also present, such as *Picea mariana* (Mill.) BSP., *Andromeda glaucophylla* Link, *Kalmia polifolia* Wang. and the like.

During a brief stop at this place last summer, Ludlow Griscom called my attention to the diseased appearance of one of the half dozen young specimens of *Picea mariana* which have survived sundry wood cutting and draining operations. On close examination, the disease proved to be a heavy infection of *Arceuthobium pusillum* Peck. Strangely enough we could find no infection on any other spruce despite the fact that the branches of the nearest neighbor were actually interlocked with those of the diseased tree. Thus does the survival of the dwarf mistletoe in this bog, to say nothing of the entire Concord region, hang by a very slender thread!



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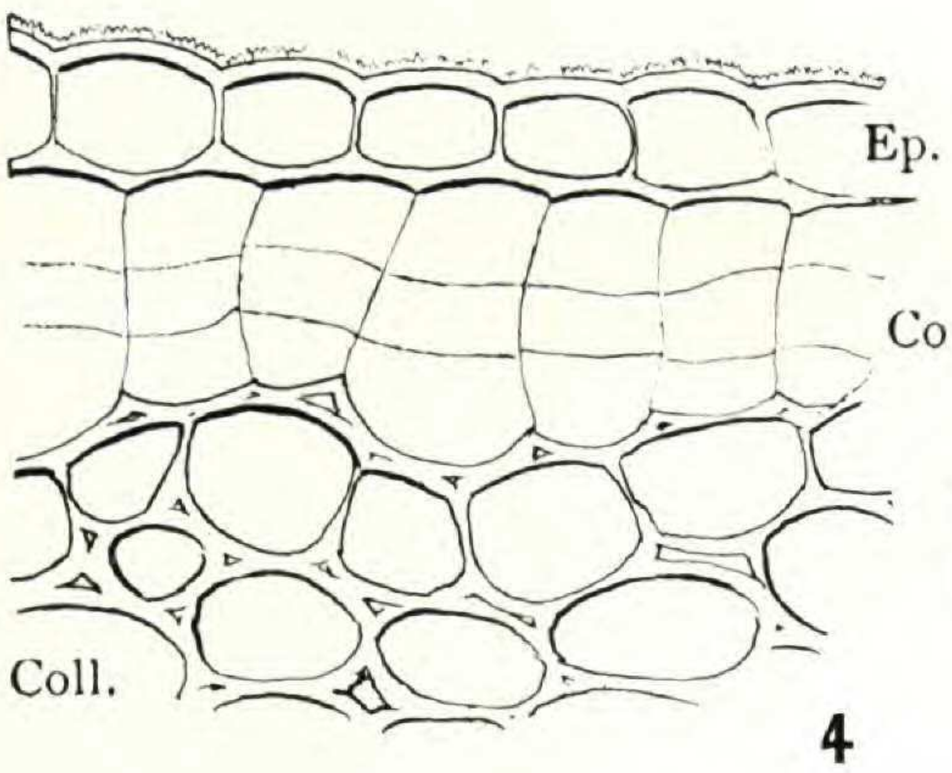

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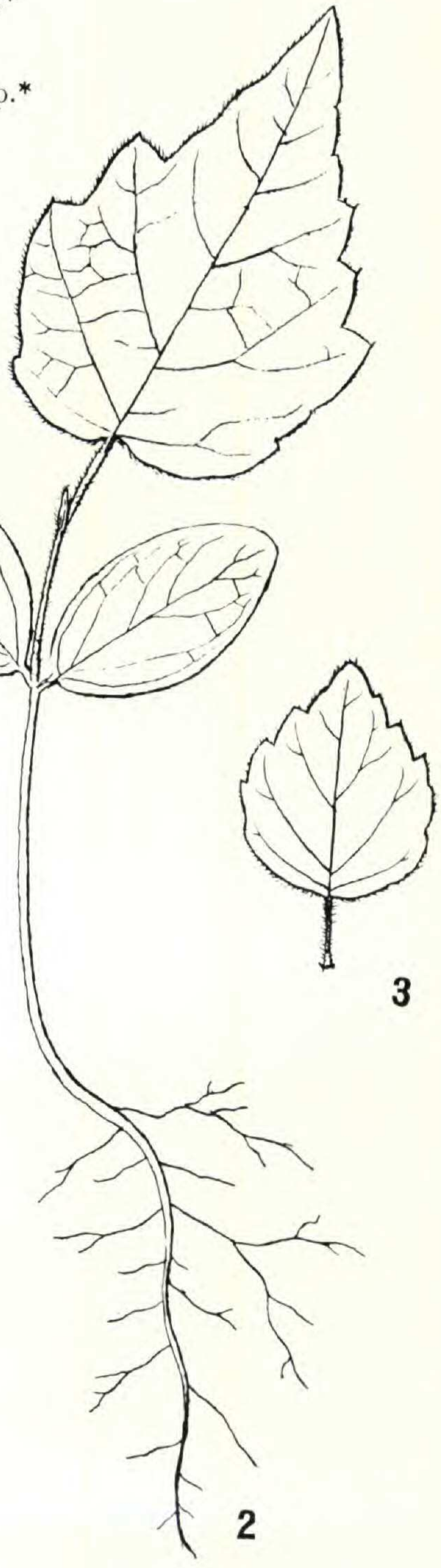

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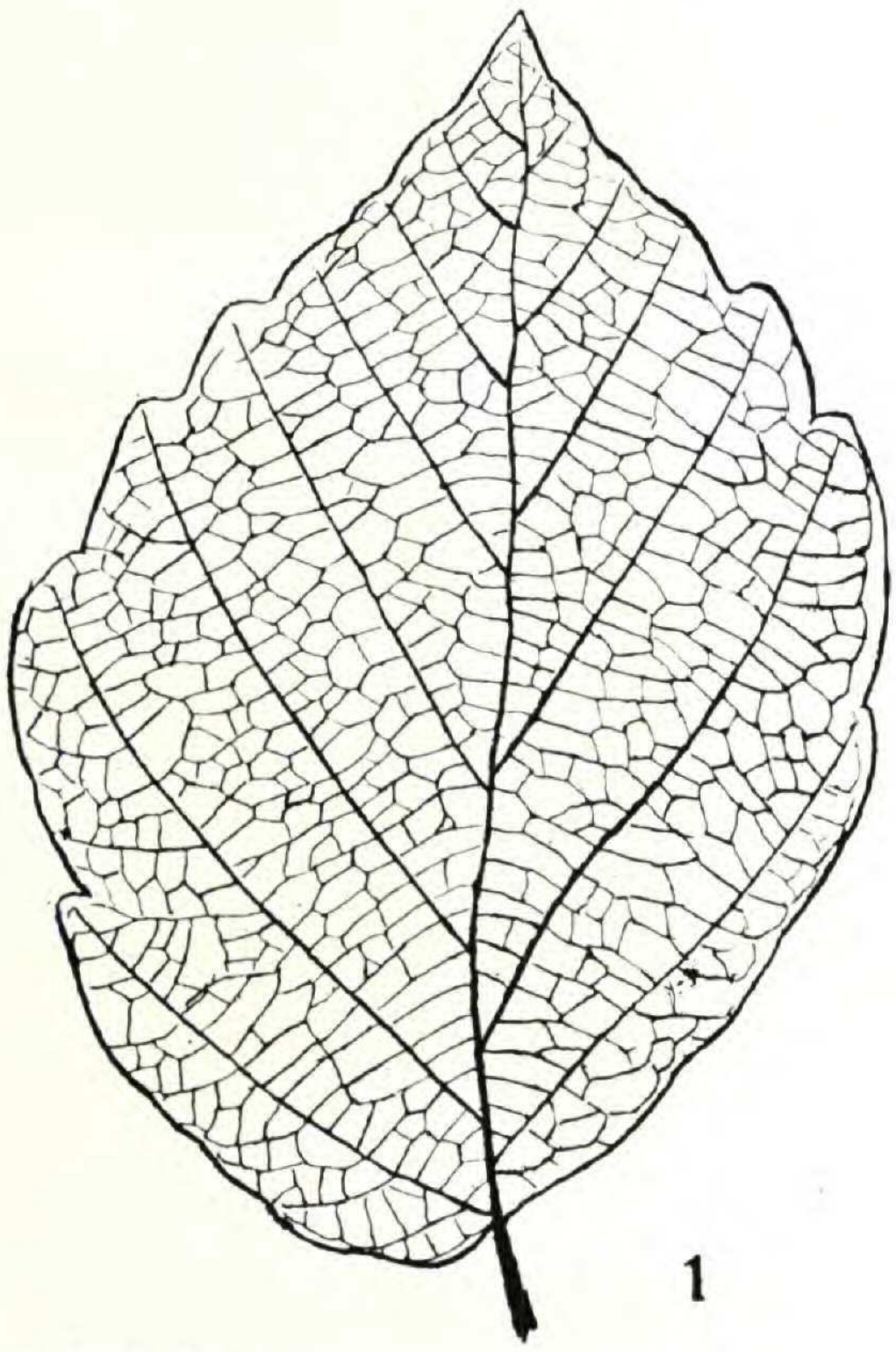

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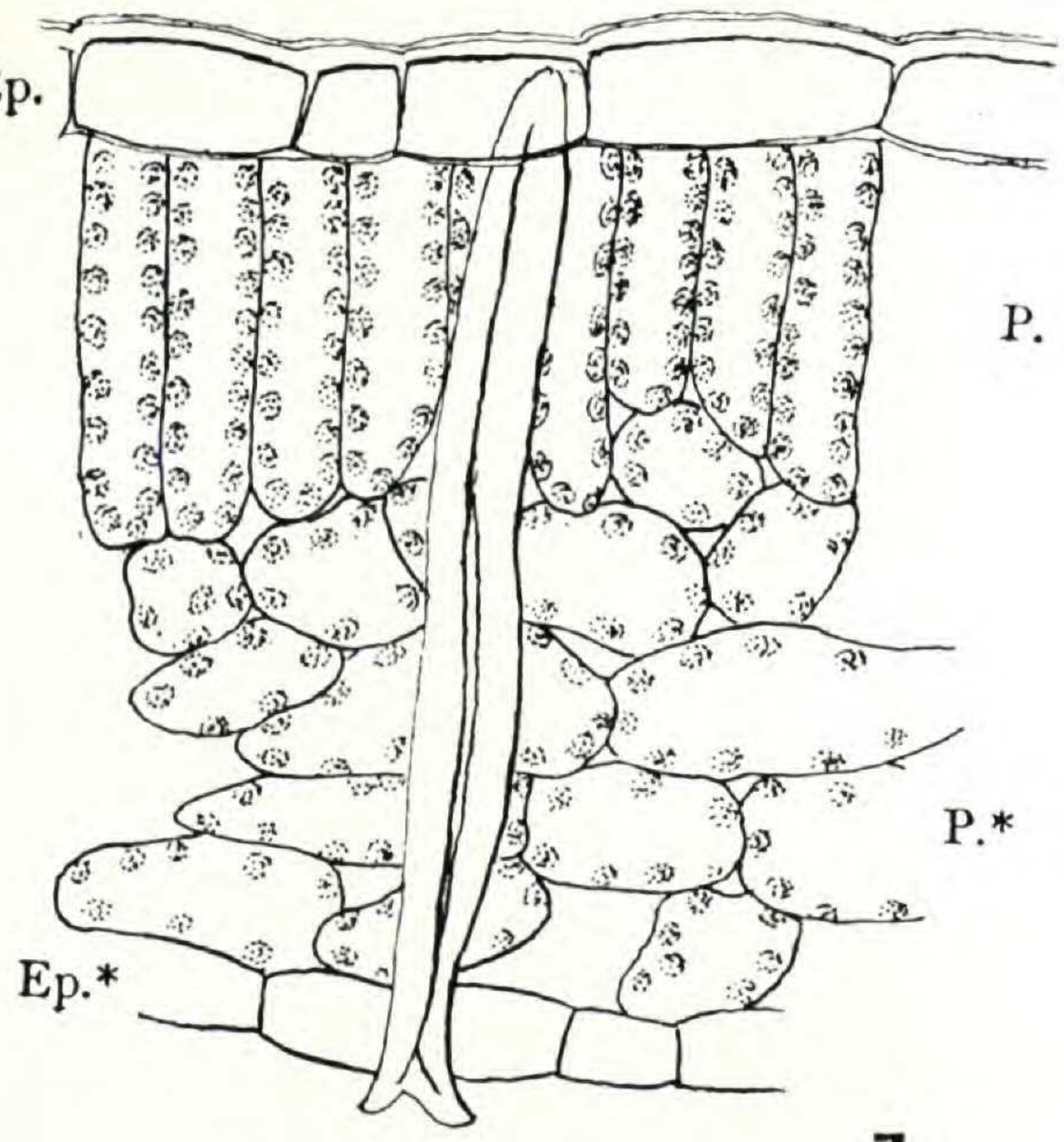
HAMAMELIS VIRGINIANA.



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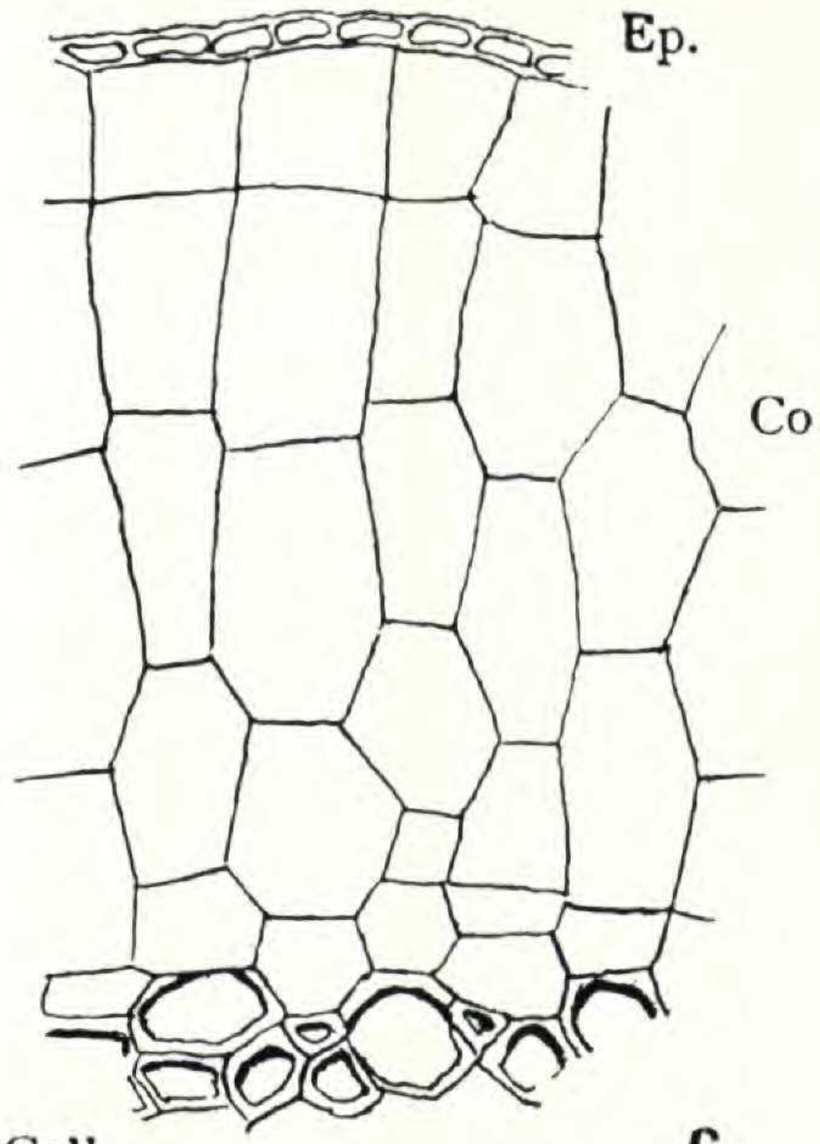

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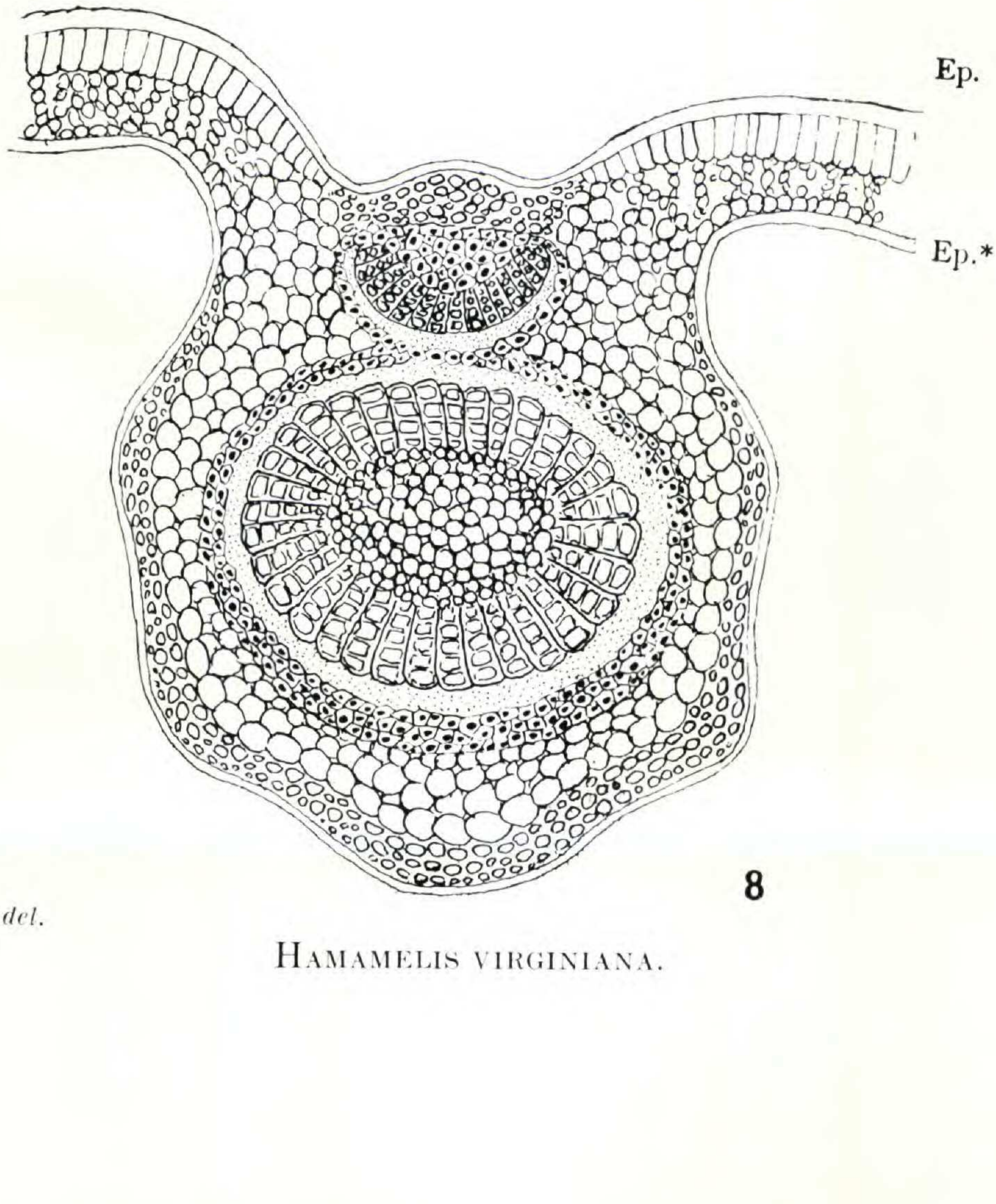

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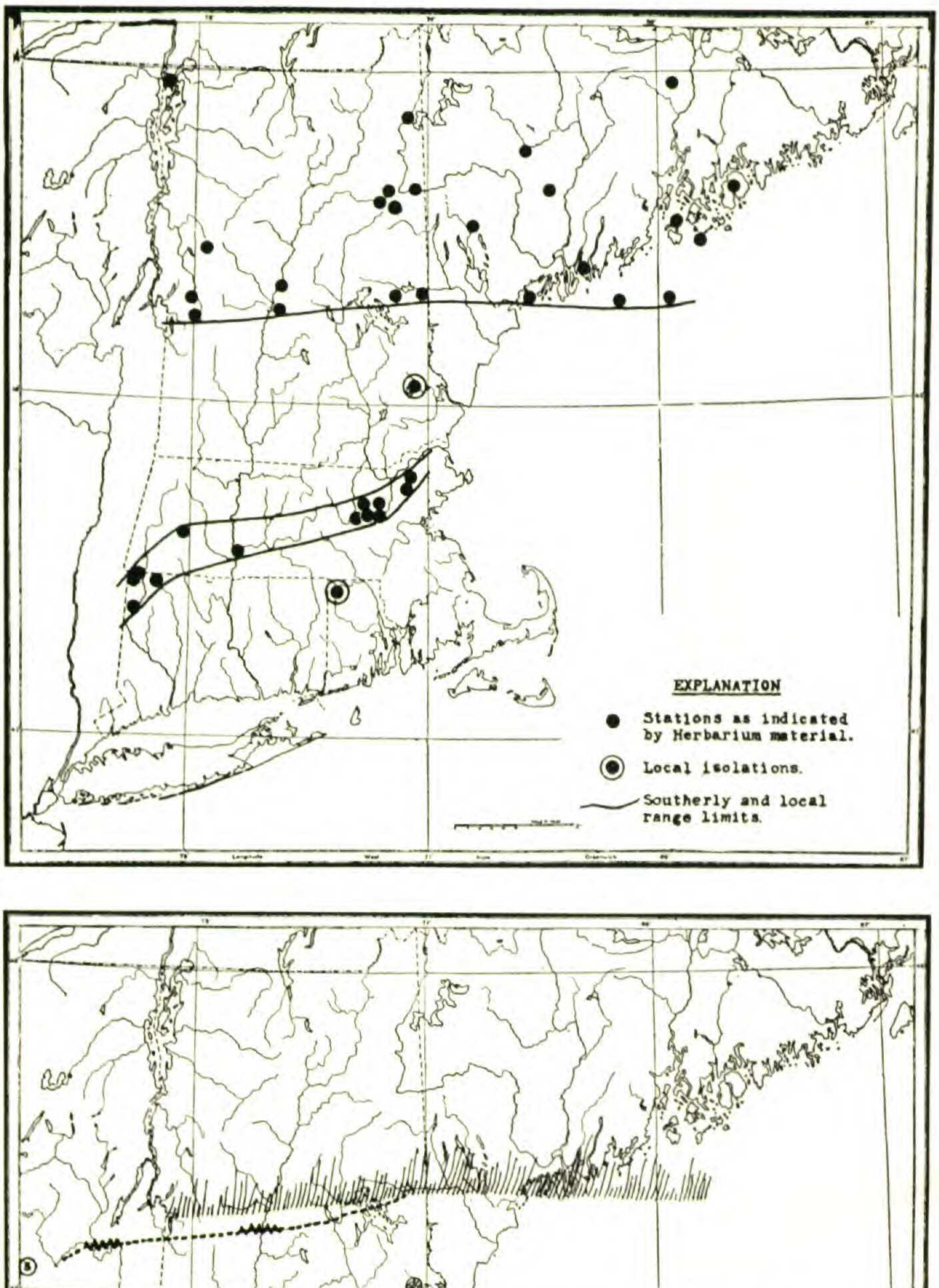
HAMAMELIS VIRGINIANA.

Returning to the bog on September 29, 1930, for fresh material and for further examination of other spruce trees in the vicinity, I collected excellent fruiting specimens, as well as staminate plants, the identity of which has been confirmed by Dr. J. H. Faull. The occurrence of both sexes of this dioecious parasite on a single host tree is exceptional (Thoday & Johnston, Ann. Bot. p. 393, XLIV, April, 1930). Close scrutiny failed to reveal the slightest trace of infection on any other spruce, which is the more surprising in the light of the presence of fertile plants.

An interesting symposium on dwarf mistletoe was published in RHODORA for January, 1900, with excellent plates illustrating the external characteristics of the plant, its effect on the host and the method of seed dissemination. It is astonishing to learn that the parasite was unknown to science prior to 1871. It was considered an extremely rare and local plant as recently as 1899. At present it is regarded as widely distributed throughout the limit of its range, occurring in the six New England states, New York, New Jersey (*L. Griscom*), Pennsylvania, Michigan, Wisconsin, and northward. On the recent authority of Thoday & Johnston (supra), J. H. Faull and others, *A. pusillum* occurs chiefly as an endophytic parasite in the tissues of its principal host, *Picea mariana*, but can spread to *P. canadensis* (Mill.) BSP., *P. rubra* (Du Roi) Dietr., and very exceptionally to *Larix laricina* (Du Roi) Koch. Externally, it appears to be confined to a very definite region of the infected twigs. Full-grown aerial shoots in August with ripening fruits occur mainly on the three-year old stem and occasionally on the upper part of the four-year old stem. Shoots with nearly mature flowers occur on the two-year old twigs. The parasite is not visible as a rule on one-year old or current year growth, although its endophytic system grows forward keeping pace each season with the growth of the host twig. The ovary of the mature plant contains a single ovule covered with a sticky glutinous substance which facilitates transportation by birds and lodgement on a host twig. Faull asserts that germination occurs only on live twigs of the host, and apparently only at particularly favorable spots on the twig. Such a condition indicates that unusual germination factors are necessary for the propagation of the species. This conclusion is of importance in judging the significance of certain observations in subsequent paragraphs of this article.

In view of the fact that *Arceuthobium* is very easily overlooked the



Map 1 (upper). Distribution of *Arceuthobium pusillum* in central and southern New Englamd.

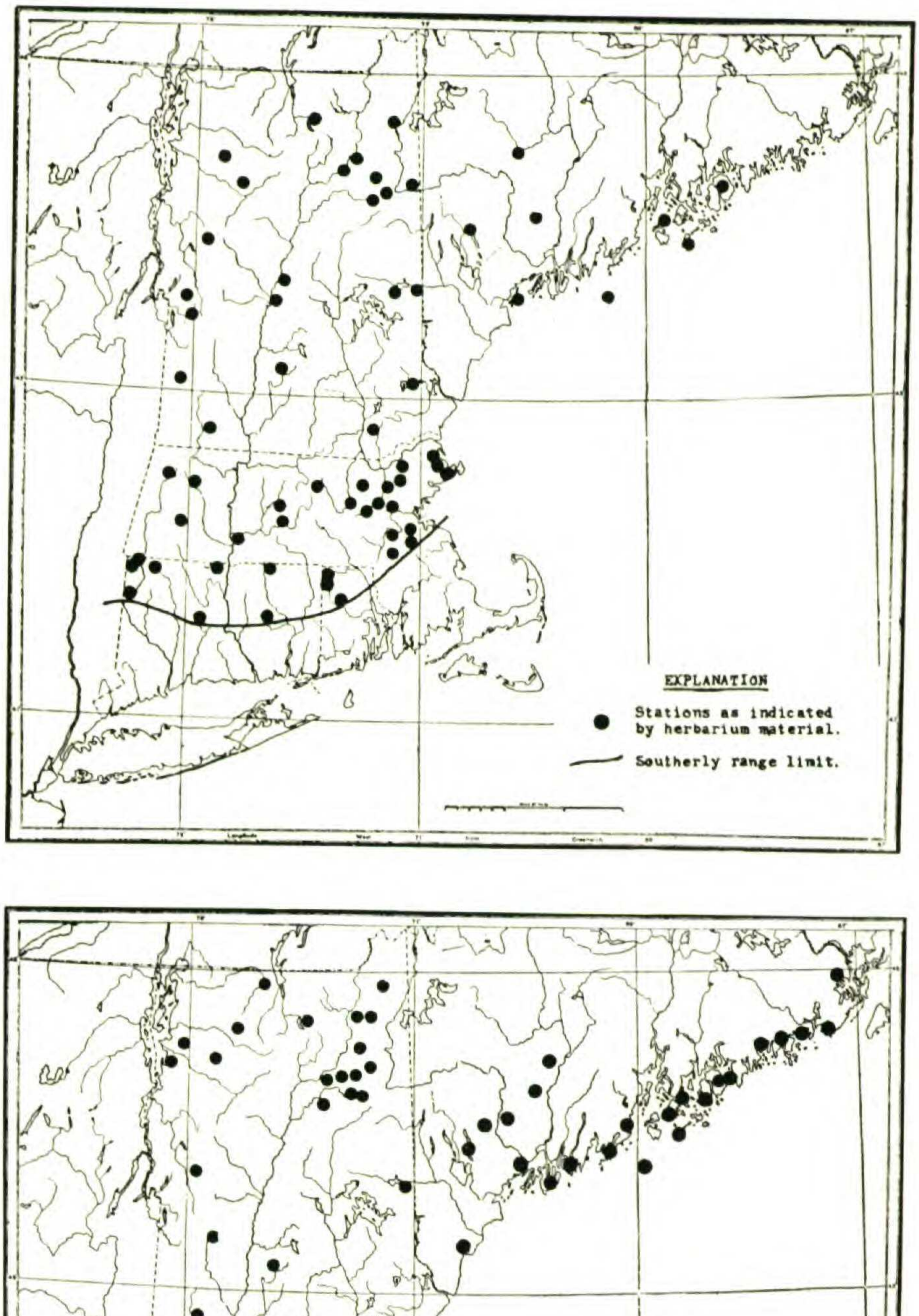
Map 2 (lower). Position of Moraines of the last (Wisconsin) advance of the Pleistocene glaciations (after *Antevs*) compared with southern limits of *A. pusillum*.

existing records of its occurrence in southern New England, as determined by the specimens filed at the Gray Herbarium, at Arnold Arboretum, and in the herbarium of the New England Botanical Club,[1] perhaps are not particularly significant. The remainder of this article must be read with this clearly in mind. Exclusive of Maine, where the plant is widely distributed, there are collections of dwarf mistletoe from only twenty-eight New England towns (MAP 1). Of these, nine are from Massachusetts, four from Connecticut, and one from Glocester, Rhode Island. Curiously enough, if we consider the Glocester station as a local isolation, the remaining thirteen southern New England stations form a narrow straight belt, closely paralleling and seventy-five miles north of the terminal moraine[2] of the last glaciation. This belt extends from Andover, Massachusetts, to Salisbury, Connecticut, through Wilmington (Massachusetts), Concord, Acton, Lancaster, Clinton, Boylston, Springfield, Becket, Norfolk (Connecticut) and Kent. The new Concord station is the most southeasterly one in Massachusetts. To the northward, there is a wide gap of 80–100 miles from which we have no herbarium material except from a single station at Nottingham, New Hampshire. The most southerly limit of this secondary belt (from present available information) is marked by the line: Matinicus Is. (Maine), Monhegan Is., Great Chebeague Is., Effingham (New Hampshire), Lebanon, Rutland (Vermont).

At the present writing there appears to be no reasonable explanation for this curious representation in the three herbaria consulted other

[1] A thorough analysis of the complete ranges of the plants discussed in this article may not be attempted without reference to all the important herbaria in North America. Lack of time and opportunity prohibits for the present an analysis of the entire North American range of *A. pusillum*, such as I have made for New England. In fact, it is probable that local collections in other sectors of the range are not sufficiently extensive to warrant an attempt at piecing together the whole picture. A continuous series of specimens by townships is the ideal data from which to work up a study of this sort. In all probability the nearest approach to this ideal, as far as any large local area is concerned, may be gained by reference to the New England material contained in the three botanical establishments which I have consulted. The precise distribution of plants within the limits of central and southern New England is sufficiently well known to justify a certain degree of reliance on any conclusions derived from existing records within this area.

[2] Following Antevs (The Last Glaciation, p. 164; Am. Geog. Soc. 1928) I have sketched the three southerly positions of the retreating Wisconsin ice which represent halts of sufficient duration to have produced terminal moraines (MAP 2). It is indeed remarkable that the primary and secondary range-limits of *Arceuthobium* are substantially on the identical lines indicated by Antevs as major intermediate resting stages during the retreat of the ice sheet. No explanation is offered, if indeed any rational explanation is possible.



Map 3 (upper). Distribution of *Picea mariana* in central and southern New England.

Map 4 (lower). Distribution of *Ledum groenlandicum* in central and southern New England (Maine stations incomplete) and the southerly range-limit of *Vaccinium oxycoccus*.

than the merest coincidence. Hence, records accompanied by vouchers from other localities in southern New England would be welcome in order that the true distribution may be determined. However, should it become an established fact that *Arceuthobium* occurs in New England south of 43° 50′ parallel only in an isolated narrow belt (except for the two anomalous outposts previously mentioned at Glocester, Rhode Island, and Effingham, New Hampshire), a problem at once arises which may have subtle ramifications.

Primarily, the distribution of *Arceuthobium pusillum* is determined by that of its two principal hosts, *Picea mariana* and *P. canadensis*. From the meagre evidence in hand, there seem to be striking inconsistencies in the ranges of hosts and parasite. For instance, it is not apparent why *Arceuthobium* should not occur, if indeed such is the case, in the general region, Ashburnham, Ashby, Rindge and Winchendon where *P. mariana* is abundant in the numerous sphagnum bogs of that ill-drained divide between two water-sheds. Again, it is strange that the scattering of spruces in three other sphagnum bogs in Concord should not harbour the parasite, all the obvious ecological conditions being just as satisfactory as at the *Ledum* station.

Some secondary set of influences must operate to restrict the occurrence of *Arceuthobium* to a range strikingly localized in comparison with that of *Picea*. Specimens of black spruce (MAP 3), for example, are noted from twenty-two towns in six counties in Massachusetts, from Ipswich and Foxboro in the east to Adams and Becket in the Berkshires. There are three stations represented from Rhode Island and eight from Connecticut. Its southerly limit of distribution runs through Canton (Massachusetts), Foxboro, Scituate (Rhode Island), Southington (Connecticut) and Kent, for the most part exactly paralleling the limit of range of *Arceuthobium* but about thirty miles to the southward. Obviously, some limiting factors are at work to prevent the dwarf mistletoe from occupying a range essentially coincident with that of black spruce.

There are two curious facts or coincidences concerning *Arceuthobium* which may be suggestive. The first has already been alluded to: at Concord the parasite shows no disposition to spread from the infected spruce to its contiguous neighbor even though the branches of both trees are more or less interwoven. Such a condition at once suggests the remote possibility of a symbiotic association of some sort, although I must confess that the idea is novel to say the least when

applied to vascular parasites. Improbable though it may be, it is not inconceivable that *Arceuthobium* is associated with and perhaps dependent for its complete development on some fungus or bacteria which requires two hosts for the completion of its life cycle. Perhaps the parasite will attack only those individual specimens of spruce and larch which previously for some reason have become weakened. Following out this latter line of thought, it may be found that a small percentage of the host trees are subject to some fungus or other primary disease which permits *Arceuthobium* to gain a foothold. As the southern limit of *Picea* is approached, individual specimens become more and more sparsely distributed in locally isolated bogs. It would follow, logically enough, that the numbers of weakened host trees would diminish and perhaps disappear entirely at the extreme southerly range-limit where stations for spruce are relatively widely separated. By postulating a primary disease to which *P. mariana* is the most and *L. laracina* the least susceptible of the four known hosts of *A. pusillum*, we provide a simple explanation for the extraordinary discrimination which the parasite displays. In this connection, it is pointed out that I found only one specimen of *A. pusillum* on *L. laracina* (Arnold Arboretum: Kent, Connecticut, *Austin & Eames*, 11 May, 1903) among all the material which I examined in the three herbaria despite the fact that the larch is probably just as common as *P. marina*, if not more so, in Massachusetts, Rhode Island and Connecticut.

The second fact relates to an evident similarity in the ranges of *A. pusillum* and certain northern heaths, notably *Kalmia polifolia* and *Ledum groenlandicum*. A detailed range-study of the entire series of the normal sphagnum bog associations, including the cryptogams, should be made before we are justified in attaching much significance to this phenomenon. The occurrence of *Ledum* and *Arceuthobium* in close association in a small bog in Concord along the extreme southeastern limit of range of each species, and nowhere else so far as I know within a radius of approximately eight miles, seemed so curious that I plotted the southern New England distribution of *Ledum* (map 4). Except for two locally isolated stations, at Canton, Massachusetts, and Litchfield, Connecticut, and for the *Arceuthobium* station at Glocester, Rhode Island, the southeasterly limits for both species coincide in a most striking fashion. Subsequently, I tested the distribution of four other conspicuous bog plants, in order

to avoid placing undue emphasis solely on *Ledum* as possessing a definite relationship to the occurrence of *Arceuthobium* and *Picea*. The species selected were: *Eriophorum spissum* Fernald, *Kalmia polifolia* Wang., *Andromeda glaucophylla* Link, and *Vaccinium Oxycoccus* L. Of these four random species, the range of *K. polifolia* alone exhibits features comparable to that of *Ledum*, although it occurs much more commonly along its southern limit than either *Arceuthobium* or *Ledum*. Unlike the latter, it is locally isolated at Glocester (Rhode Island) in close association with *Arceuthobium*.

Of the remaining three species, *Eriophorum spissum* occurs at Provincetown (Massachusetts), Glocester (Rhode Island), and Waterbury (Connecticut) as the southern limit of its range, thus bearing no similarity to that of dwarf mistletoe. *Andromeda* exhibits a range comparable to that of *Picea mariana*, from Norfolk County in eastern Massachusetts through Glocester (Rhode Island) to Danbury in southwestern Connecticut. *Vaccinium Oxycoccus* is likely to occur wherever suitable sphagnum bogs exist and is known from Provincetown, Nantucket, Block Island and Ronkonkoma (Long Island, New York) along a line substantially coinciding with the Wisconsin terminal moraine.

The suggestion that *Arceuthobium* may depend in some obscure manner on the presence of *Ledum*, *Kalmia*, or for that matter any other bog associate, cannot be considered very seriously without much more evidence. Copious as it is, the material examined is too meagre to warrant generalization.[1] A more accurate knowledge of the true ranges, past and present, of the various plants under discussion is

[1] Much emphasis has been laid on mere coincidence resulting from insufficient field data as a probable interpretation of my observations. As a matter of fact, I feel that coincidence is effectually ruled out by the law of chances. Assuming that the distribution of *Picea* is the sole factor in determining that of *Arceuthobium*, except as modified by the less aggressive nature of the latter, owing to limitations of seed dissemination, fecundity, and kindred restrictive influences, one would certainly expect to find scattering stations of *Arceuthobium* throughout the entire range of *Picea mariana* and *P. canadensis*. Because of the insignificant aspect of *Arceuthobium*, we properly might expect a far greater representation of spruce than of dwarf mistletoe in our herbaria, but we also properly would expect to find no essential discrepancies in distribution. The three herbaria contain specimens of *Arceuthobium* from about fifty New England stations and perhaps three times that number of *Picea mariana*. If mere chance is the sole distributional factor the mathematical chances are indeed slim for the fifty *Arceuthobium* stations to fall into two well defined belts which appear to be correlated with several other sets of phenomena: (1) parallelism, (2) range limits of certain bog associations, (3) glacial moraines. Any rational explanation, other than coincidence, is difficult to imagine, considering our present incomplete understanding of the problem. Nevertheless our instinct must prompt us to reject coincidence as altogether too unlikely.